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Semantics to Empower Services Science: Using Semantics at Middleware, Web Services and Business Levels

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THE 4 X 4 SEMANTIC MODEL

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Outline

- Motivation
- The Four Tiers
  - Modeling, Enactment, Partner Services and Execution
- The Four Types Of Semantics
  - Data, Functional, Non-Functional and Execution
- The 4 X 4 Model
  - Unifying the four tiers using the four types of semantics
- The 4 X 4 Model In Action

Motivation

- Organizations are often involved in complex business transactions with various partners across the world
  - For example, the business decisions are made in the US, technical and support services are in India and suppliers come from China.
- Variety of factors can affect the business objectives of an organization.
- Business processes need to more agile and dynamic

Motivation

CHALLENGE is to:

1. Create enactment consistent with business objectives
2. Correlate and reflect changes across different participating entities
3. Be able to create agile and dynamic processes

Technical Services partner in India.

The Hard Problem

- Create partner-level requirements that are consistent with those of the business process
- Verify the correctness of the enactment with respect to the business process modeling
- Select and configure the partners at run time
- Identify and adapt efficiently to the various events that affect the optimality of the business process

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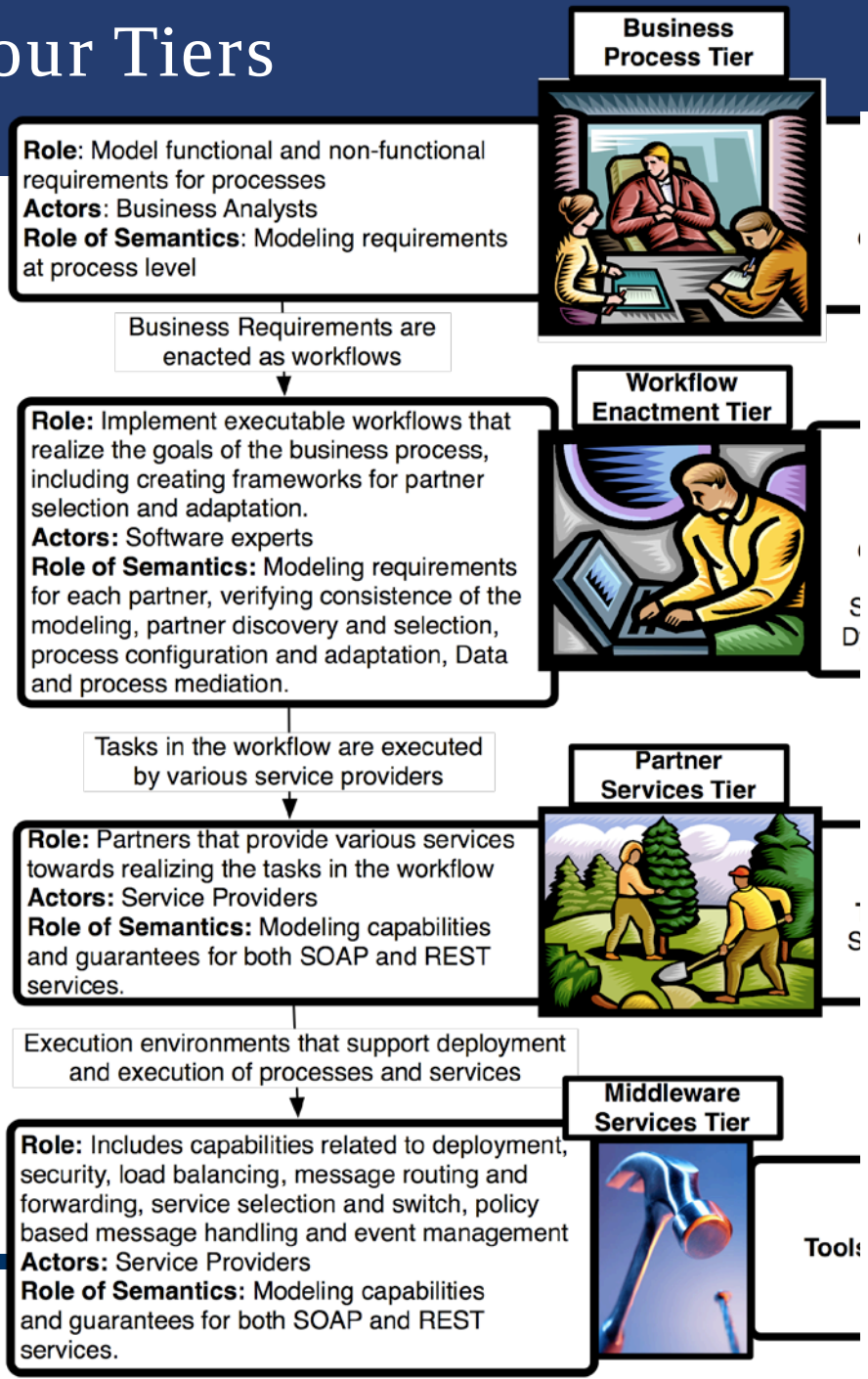
The Four Tiers



- What do I want to do?
- How am I going to it?
- Who are my partners in this?
- What is my environment for execution?

The Four Tiers

- Business Specifications Tier (referred to as business process tier in the paper)
  - Functional and non-functional aspects of the business specification are captured at this level.

    Example: Develop a SOA based solution for procuring various components to manufacture gaming hardware requests with the following constraints / requirements
    - Must support XGP graphic processing
    - Minimum 100 Gb disk space
    - Product must never be out of inventory with retailers
    - Level 3 security

The Four Tiers

- Workflow Tier
  - Actual workflow enactment of the specification.
  - Partners based on "What they do" are identified. Not Who
    - Example: Partners for the parts ordering specification are
      - Suppliers for Graphics processor, Gaming Chip, Disk drive, Forecasting partner (to give retailer stock information and demand forecasting).
  - Process level specification is broken down into partner level specification
  - What to do when something goes wrong with this enactment (Adaptation and event identification)

The Four Tiers

- Workflow Tier (Contd..)
  - Example partner requirement
    - Disk Drive Partner:
      - Must be able to do a purchase order for hard drives
      - Will send PORequest according to Rosetta PO and expect a POResponse conforming to RosettaNet
      - Communication must be over secure 128 bit encrypted channel. (Non-functional requirement)
      - Disk capacity must be at least 100 Gb (non-functional)

The Four Tiers

- Partner Services Tier
  - Captures the capabilities and requirements of potential partner services.
    - Example of Disk drive service
      - Accept input in Rosetta RequestPO and ebXML RequestPO formats and output in Rosetta POResponse format (data)
      - Request purchase order for Hard drives (Functional)
      - 128 Bit SSL communication
      - Drives with capacities 80, 100 and 120 Gb

The Four Tiers

- Middleware Services Tier
  - Captures the services offered by containing middleware systems.
  - Includes capabilities related to deployment, security, load balancing, message routing and forwarding, service selection and switch, policy based message handling and event management.

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What does Semantics bring to the table?

- Better Reuse
  - Semantic descriptions of services to help find relevant services
- Better Interoperability
  - Beyond syntax to semantics, mapping of data exchanged between the services (very time consuming without semantics, just as XML in WSDL gives syntactic interoperability, SAWSDL gives semantic interoperability)
- Configuration/Composition
  - Enable dynamic binding of partners
- Some degree of automation across process lifecycle
  - Process Configuration (Discovery and Constraint analysis)
  - Process Execution (Addressing run time heterogeneities like data heterogeneities.)

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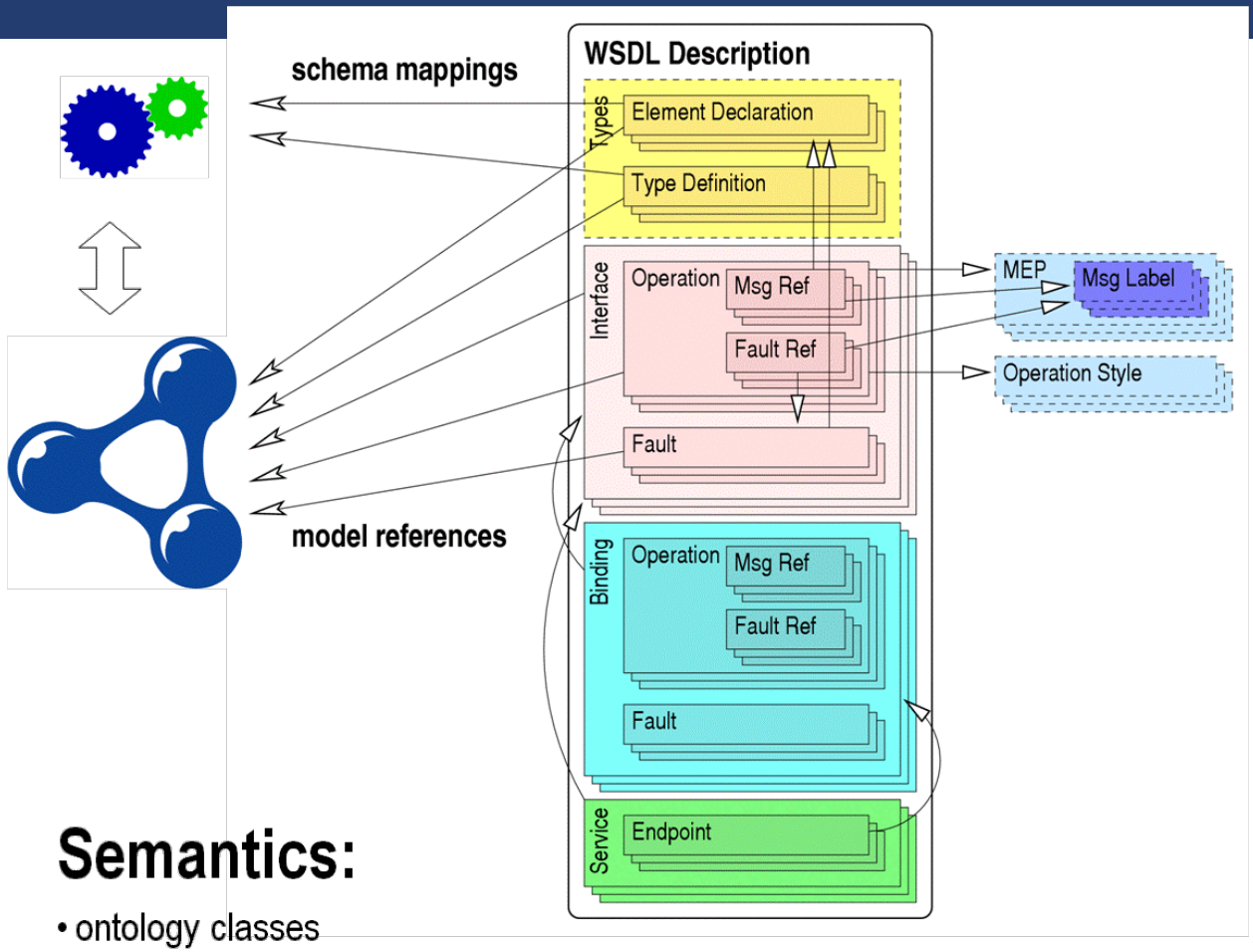
Semantics to Web Services: The ingredients

- Conceptual Model/Ontology
  - An agreed upon model that captures the semantics of domain
  - Common Nomenclature
  - Domain Knowledge (facts)
- XML based service description
  - Standards and specifications like WSDL for web service description, WS-Agreement for capturing agreements etc.
- Annotate the service description

SAWSDL at a glance

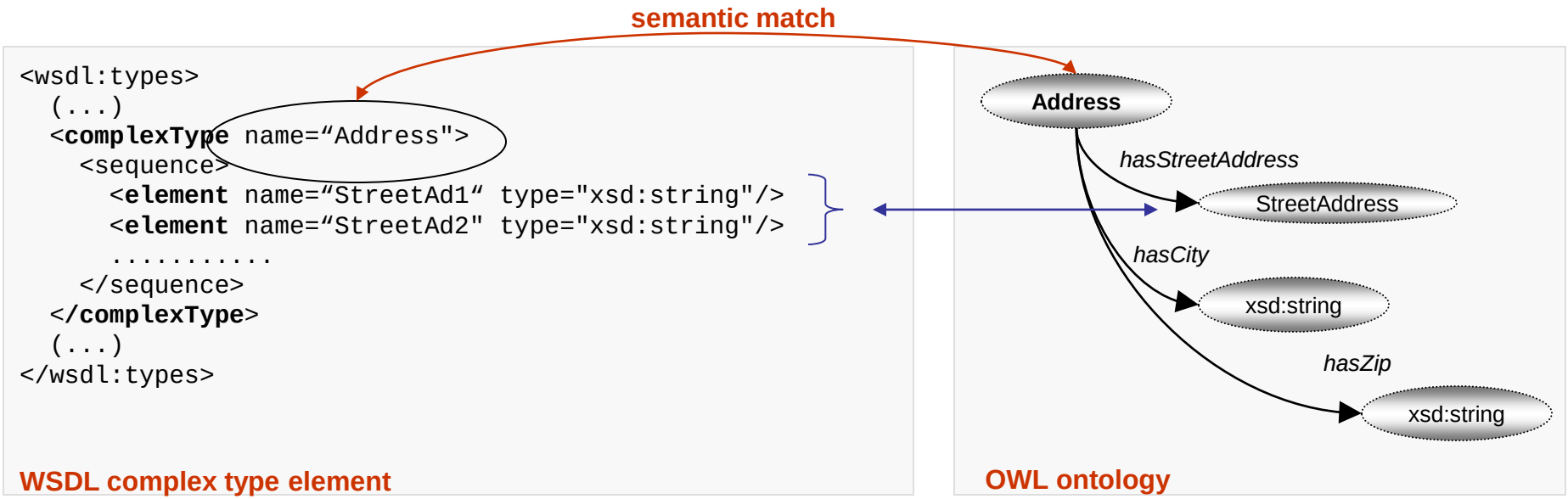


Semantics:

- ontology classes
  - discovery, composition
  - filtering, ranking
- lifting/lowering mappings
  - mediation, invocation
- functionality categories
  - publishing, discovery, composition
- anything, really

Ack: Jacek Kopecky

Annotating types



1. modelReference to establish a semantic association
2. liftingSchemaMapping and loweringSchemaMapping to provide mappings between XML and semantic model

Why use SAWSDL

- Build on existing Web Services standards using only extensibility elements
- Mechanism independent of the semantic representation language (though OWL is supported well)
- SAWSDL provides an elegant solution
  - Help integration by providing mapping to agreed upon domain models (ontologies, standards like Rosetta Net, ebXML)
  - Better documentation by adding functional annotation
- Ease in tool upgrades
  - e.g. wsif / axis invocation
- Is a W3C candidate recommendation

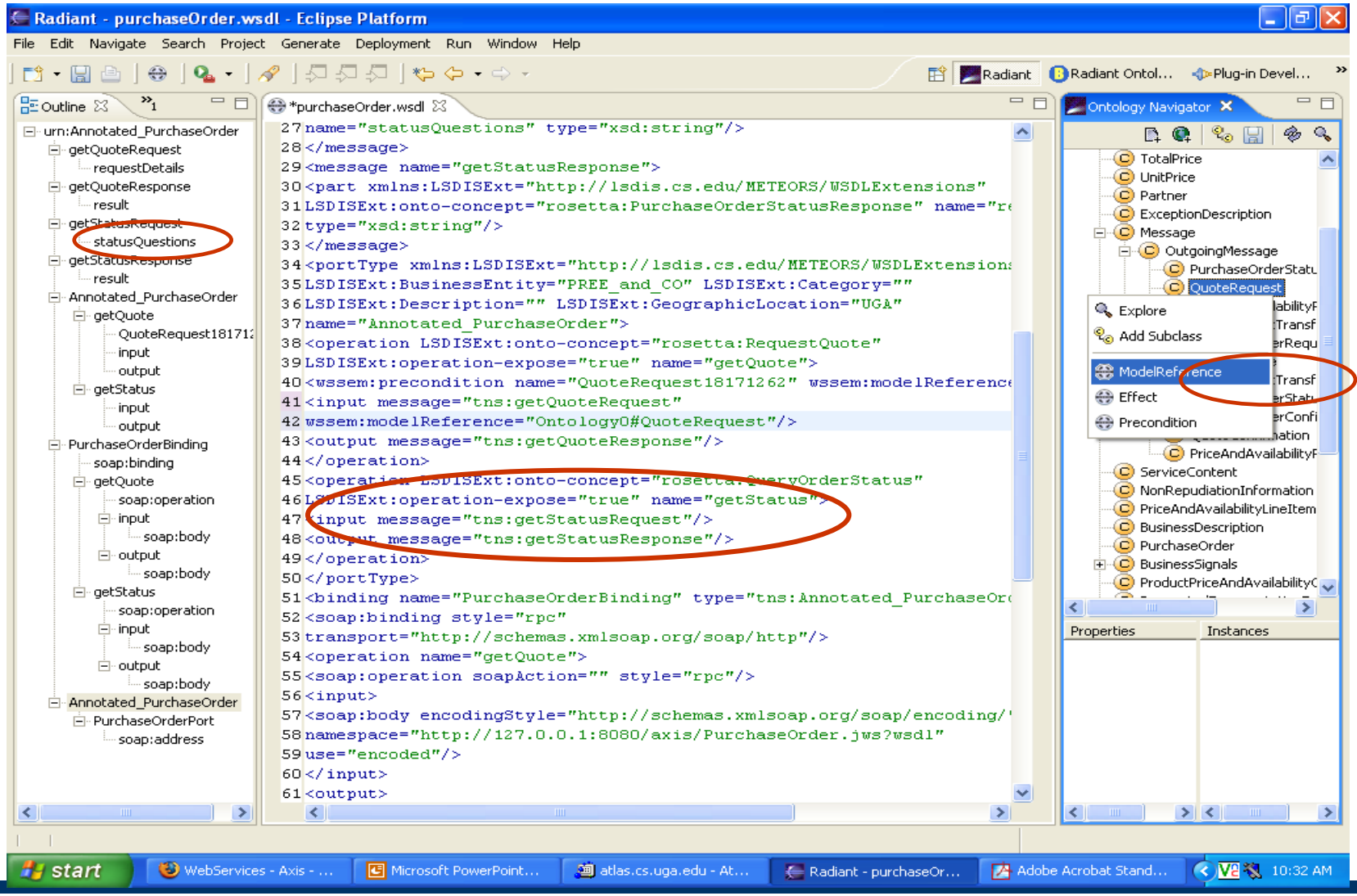
What can we support or demonstrate today

- API for handling SAWSDL documents: SAWSDL4J
- Tool for annotating WSDL services to produce SAWSDL: Radiant and for discovery: Lumina
- Using SAWSDL with UDDI for Discovery: MWSDIr
- Using SAWSDL with Apache Axis for Data Mediation
- Using SAWSDL with WS-BPEL for run-time binding
- Early Examples of SAWSDL annotated services: biomedical research

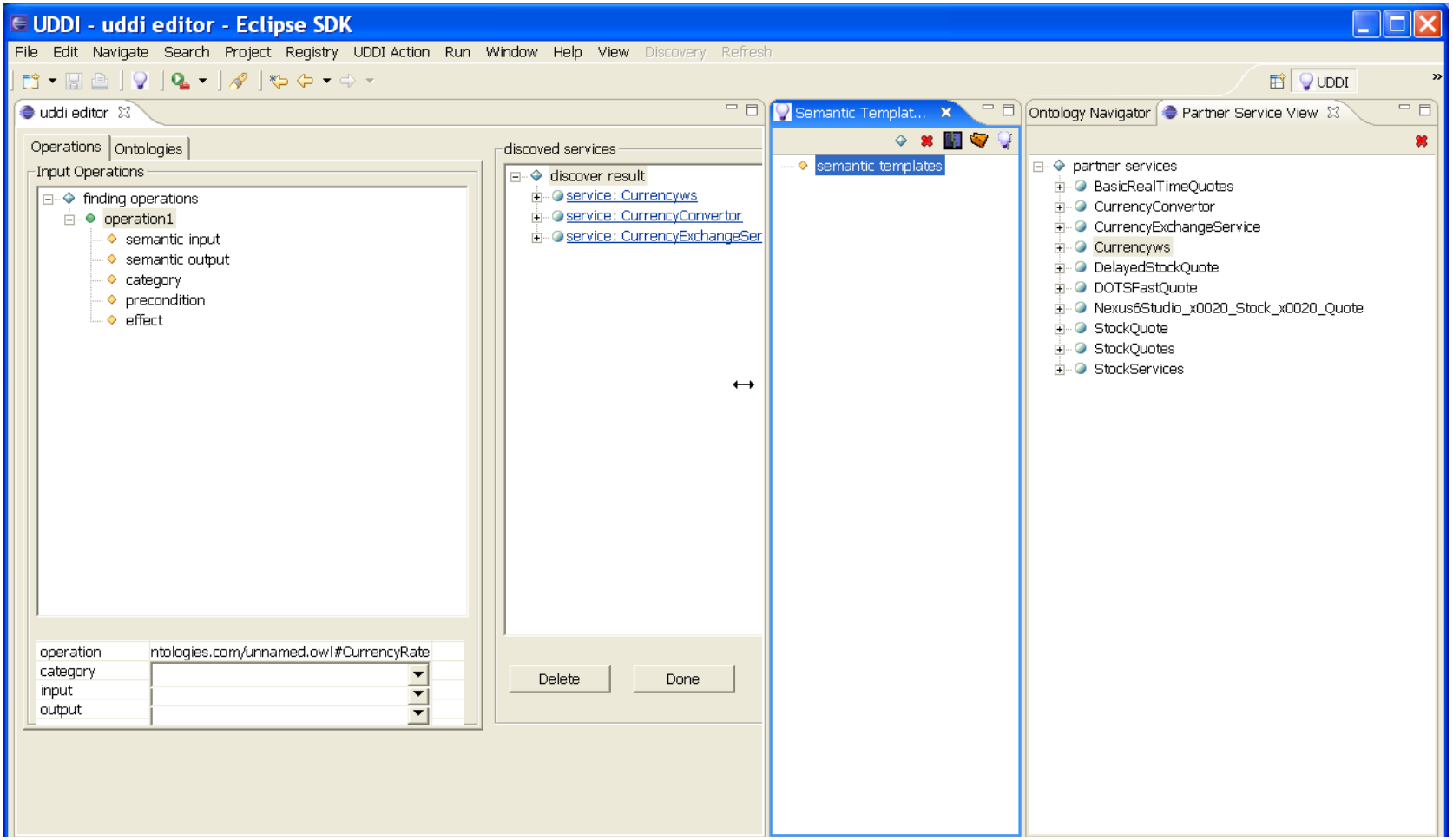
Also:

- Semantic Tools for Web Services by IBM alphaWorks
- WSMO Studio , more mentioned by Jacek

Modeling : Using Radiant



Execution: WS Discovery using Lumina (MWSDI)



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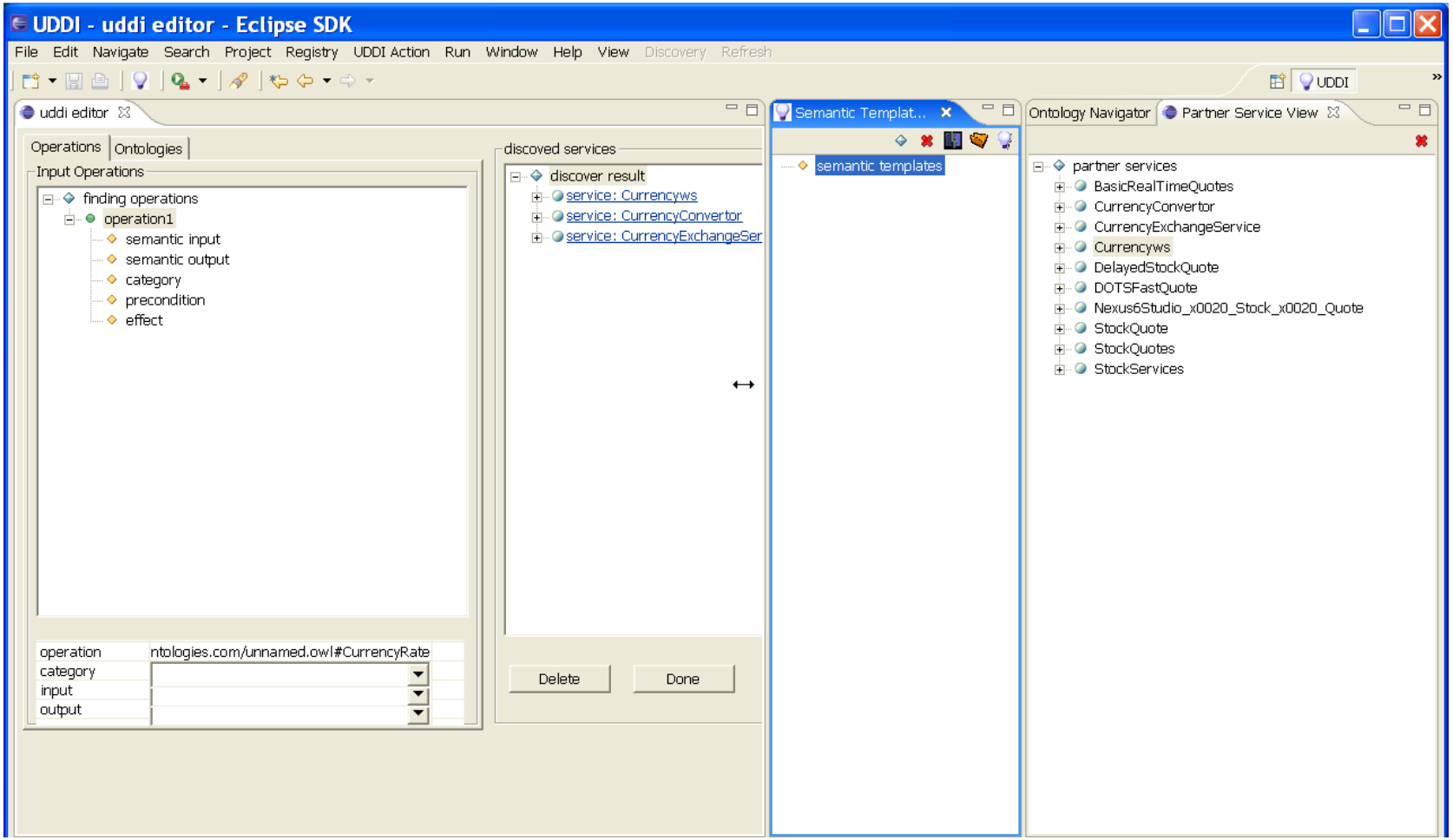
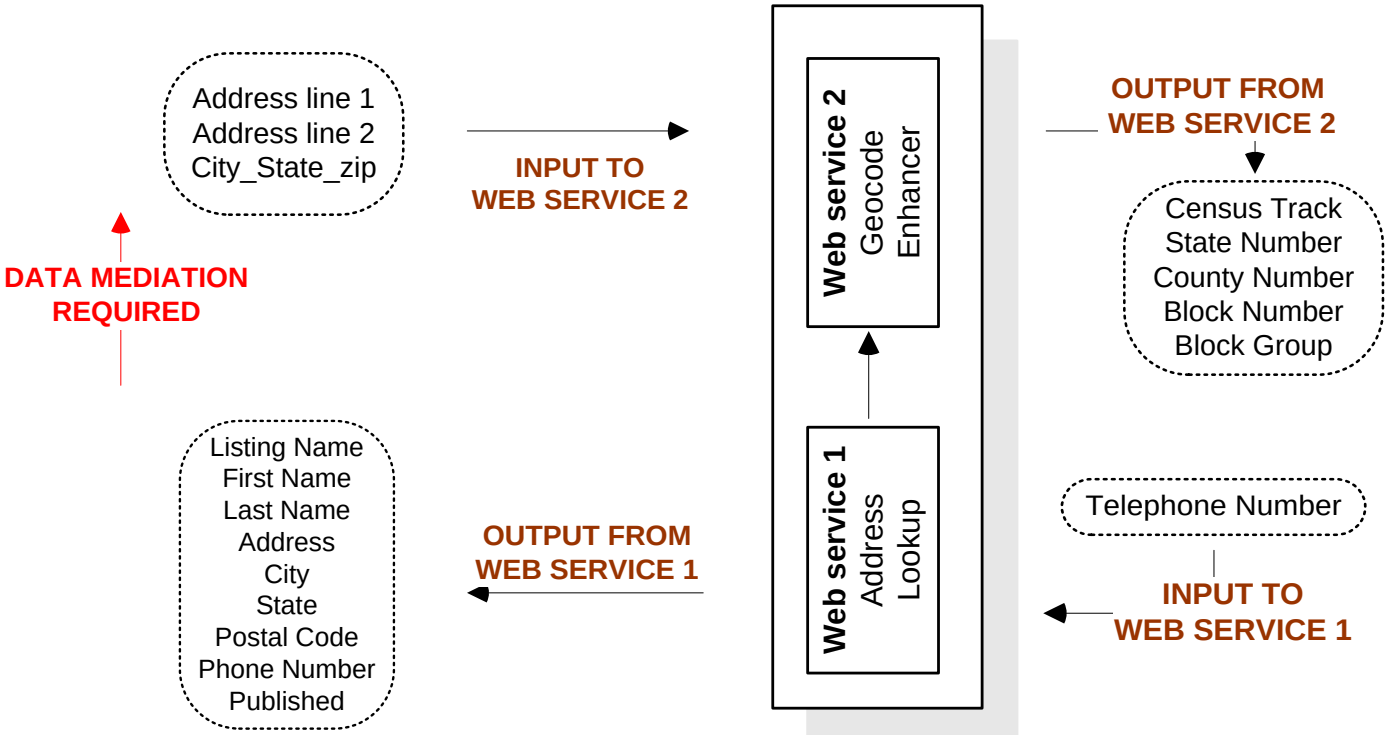
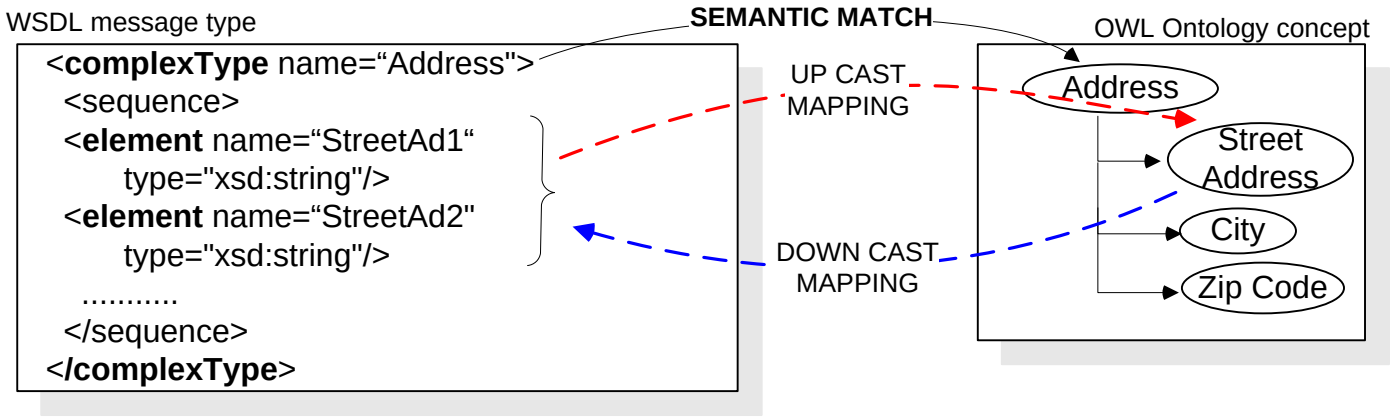


Execution: Data Mediation



Execution: Data Mediation

- User specified mappings from Web service message element to semantic model concept (say OWL Ontology)
  - upcast : from WS message element to OWL concept
  - Downcast : from OWL concept to WS message element




```
<POOntology:has_StreetAddress rdf:datatype="xs:string">
{ fn:concat($a/streetAddr1 , " ", $a/streetAddr2 ) }
</POOntology:has_StreetAddress>
```

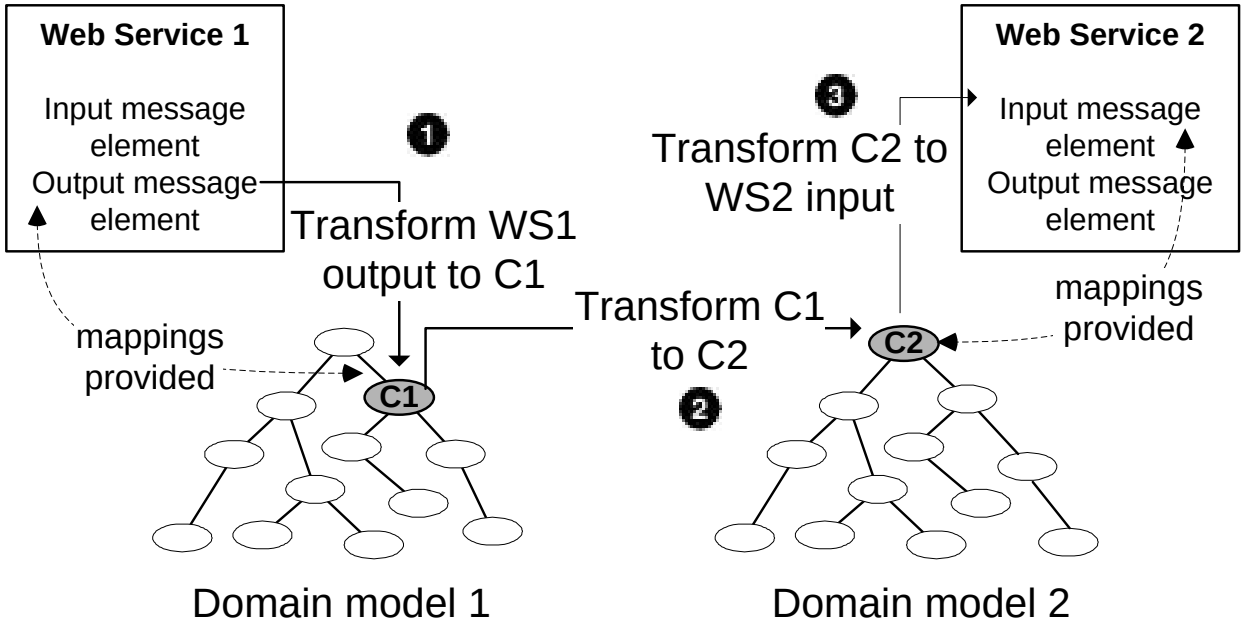
Execution: Data Mediation

Heterogeneities / Conflicts	Examples - conflicted elements shown in color	Suggestions / Issues in Resolving Heterogeneities
Domain Incompatibilities – ***attribute level differences that arise because of using different descriptions for semantically similar attributes***		
Naming conflicts Two attributes that are semantically alike might have different names (synonyms) Two attributes that are semantically unrelated might have the same names (homonyms)	***Web service 1*** Student(Id#, Name) ***Web service 2*** Student(SSN, Name) ***Web service 1*** Student(Id#, Name) ***Web service 2*** Book (Id#, Name)	A semantic annotation on the entities and attributes (provided by *WSDL-S:modelReference*) will indicate their semantic similarities.
Data representation conflicts Two attributes that are semantically similar might have different data types or representations	***Web service 1*** Student(Id#, Name) Id# defined as a 4 digit number ***Web service 2*** Student(Id#, Name) Id# defined as a 9 digit number	* Mapping WS2 Id# to WS1 Id# is easy with some additional context information while mapping in the reverse direction is most likely not possible.
Data scaling conflicts Two attributes that are semantically similar might be represented using different precisions	***Web service 1*** Marks 1-100 ***Web service 2*** Grades A-F	* Mapping WS1 Marks to WS1 Grades is easy with some additional context information while mapping in the reverse direction is most likely not possible.
Entity Definition – ***entity level differences that arise because of using different descriptions for semantically similar entities***		
Naming conflicts **S**emantically alike entities might have different names (synonyms) Semantically unrelated entities might have the same names (homonyms)	***Web service 1*** EMPLOYEE (Id#, Name) ***Web service 2*** WORKER (Id#, Name) ***Web service 1*** TICKET (TicketNo, MovieName) ***Web service 2*** TICKET(FlightNo, Arr. Airport, Dep. Airport)	A semantic annotation on the entities and attributes (provided by *WSDL-S:modelReference*) will indicate their semantic similarities.
Schema Isomorphism conflicts Semantically similar entities may have different number of attributes	***Web service 1*** PERSON (Name, Address, HomePhone, WorkPhone) ***Web service 2*** PERSON (Name, Address, Phone)	* Mapping in both directions will require some additional context information.
Abstraction Level Incompatibility – ***Entity and attribute level differences that arise because two semantically similar entities or attributes are represented at different levels of abstraction***		
Generalization conflicts Semantically similar entities are represented at different levels of generalization in two Web services	***Web service 1*** GRAD-STUDENT (ID, Name, Major) ***Web service 2*** STUDENT(ID, Name, Major, Type)	* WS2 defines the student entity at a much general level. A mapping from WS1 to WS2 requires adding a Type element with a default 'Graduate' value, while mapping in the other direction is a partial function.
Aggregation conflicts Semantically similar entities are represented at different levels of generalization in two Web services	***Web service 1*** PROFESSOR (ID, Name, Dept) ***Web service 2*** FACULTY (ID, ProfID, Dept)	* A set-of Professor entities is a Faculty entity. When the output of WS1 is a Professor entity, it is possible to identify the Faculty group it belongs to, but generating a mapping in the other direction is not possible.
Attribute Entity conflicts Semantically similar entity modeled as an attribute in one service and as an entity in the other	***Web service 1*** COURSE (ID, Name, Semester) ***Web service 2*** DEPT(Course, Sem, .., ..)	* Course modeled as an entity by WS1 is modeled as an attribute by WS2. With definition contexts, mappings can be specified in both directions.

*** Interoperation between services needs transformation rules (mapping) in addition to annotation of the entities and/or attributes indicating their semantic similarity (matching).**

Execution: Data Mediation

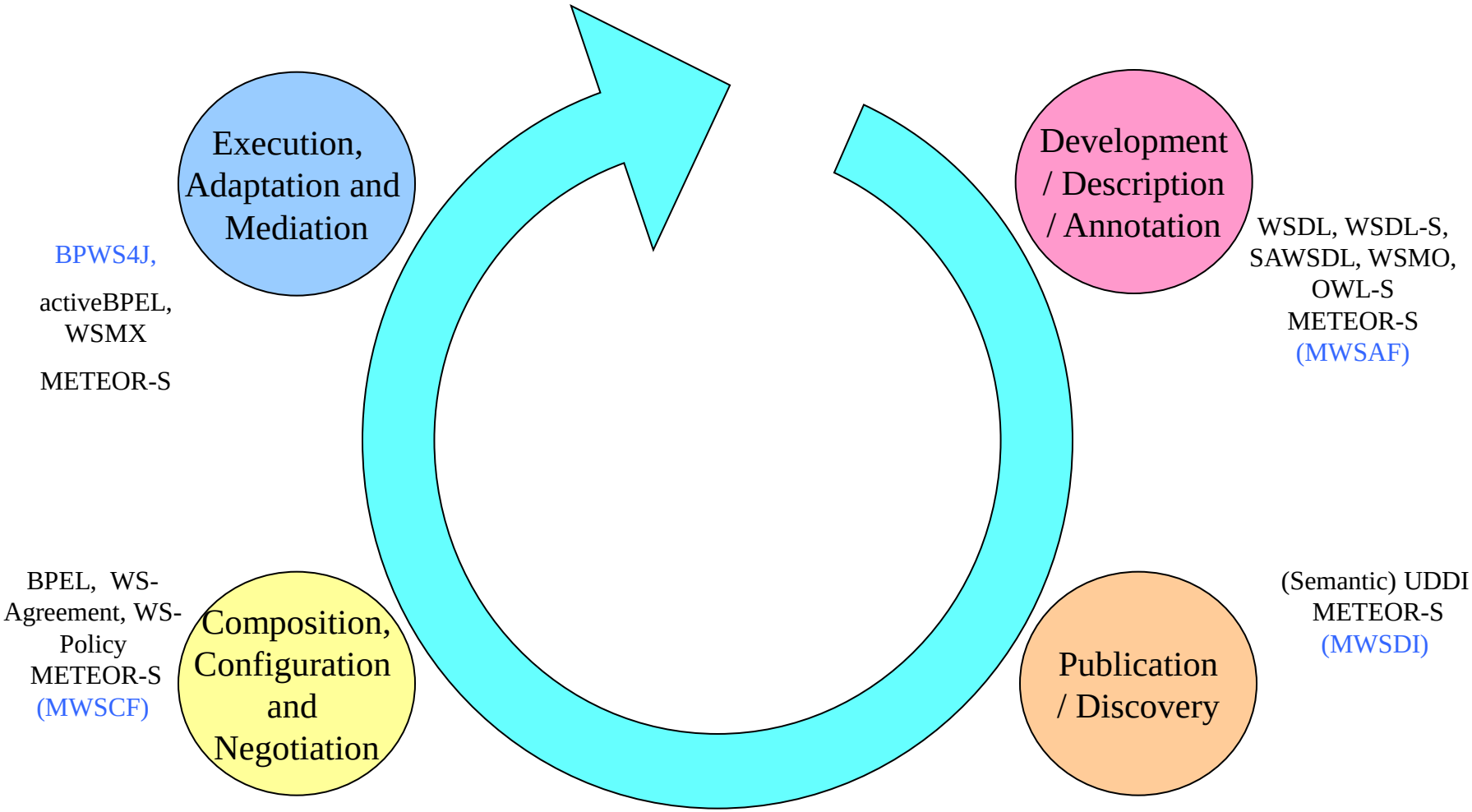
- Web services interoperate by re-using these mappings.
  - Ontologies now a vehicle for Web services to resolve message level heterogeneities



Four types of semantics

- Data Semantics: What are the inputs and outputs of a service
- Functional Semantics: What does a service do?
- Non-Functional Semantics: The non-functional requirements and capabilities of a service
- Execution Semantics: What is the execution context and the task skeleton (execution states) associated with this service

Semantics for Technical Services



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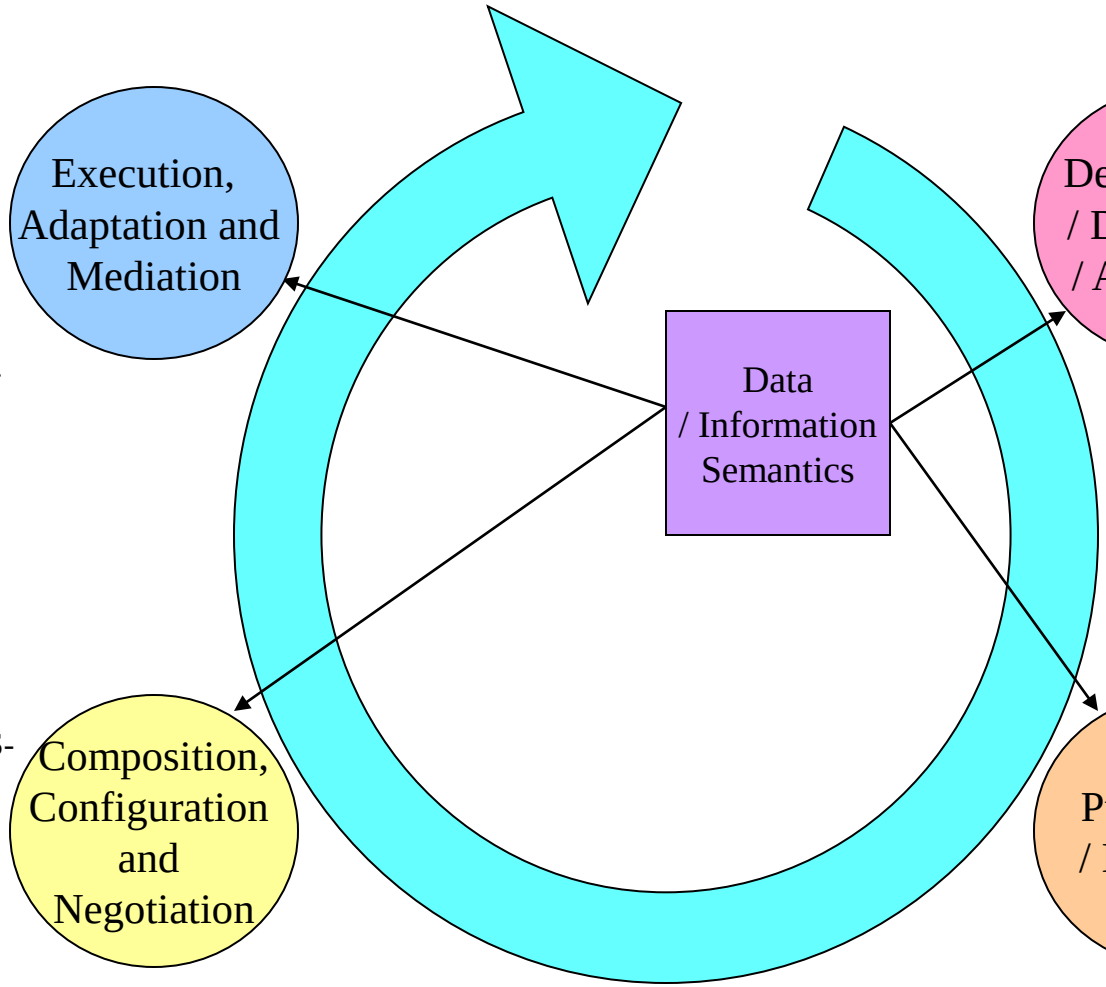

BPWS4J,
activeBPEL.
WSMX
METEOR-S

WSDL, SAWSDL, (OWL-S, WSMO, WSDL-S)
METEOR-S
(MWSAF)

BPEL, WS-Agreement, WS-Policy
METEOR-S
(MWSCF)

(Semantic) UDDI
METEOR-S
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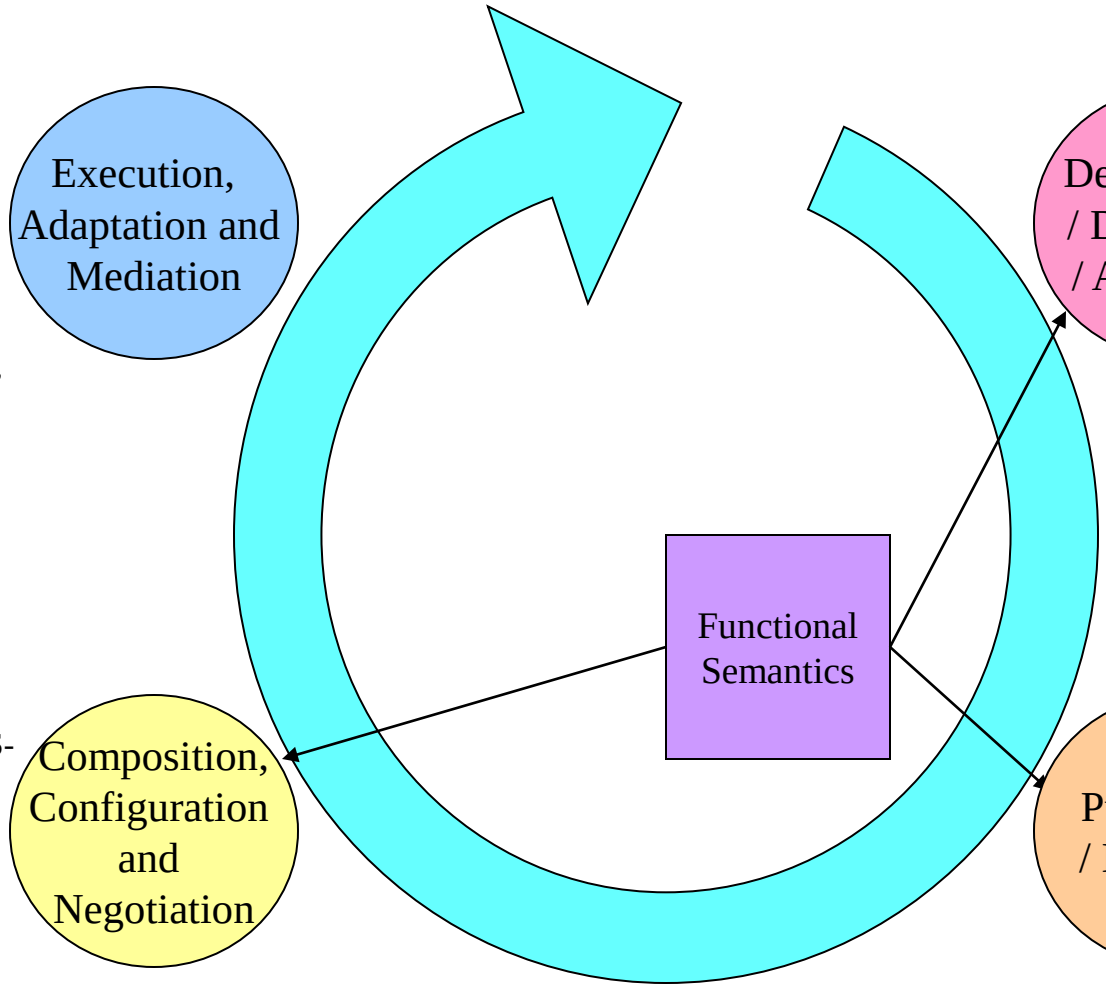

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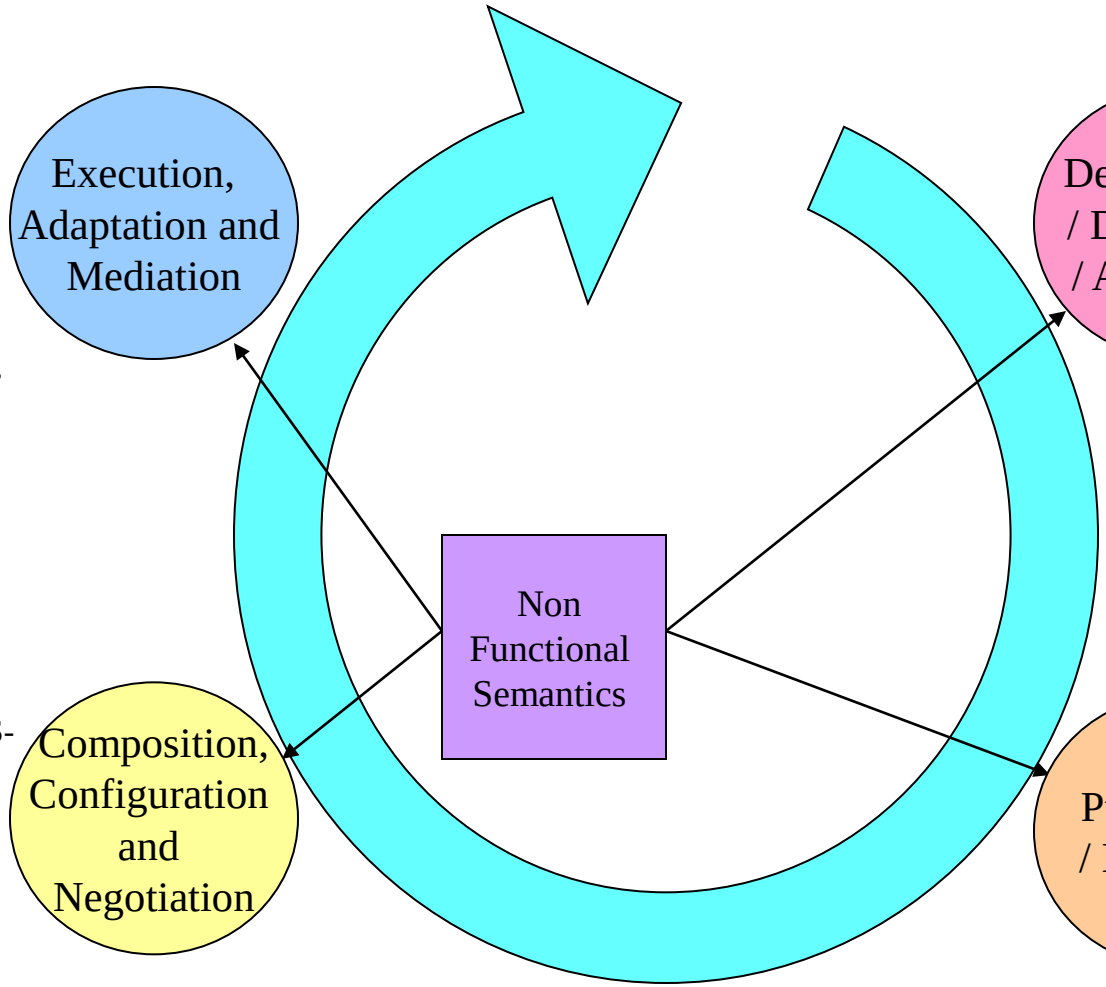

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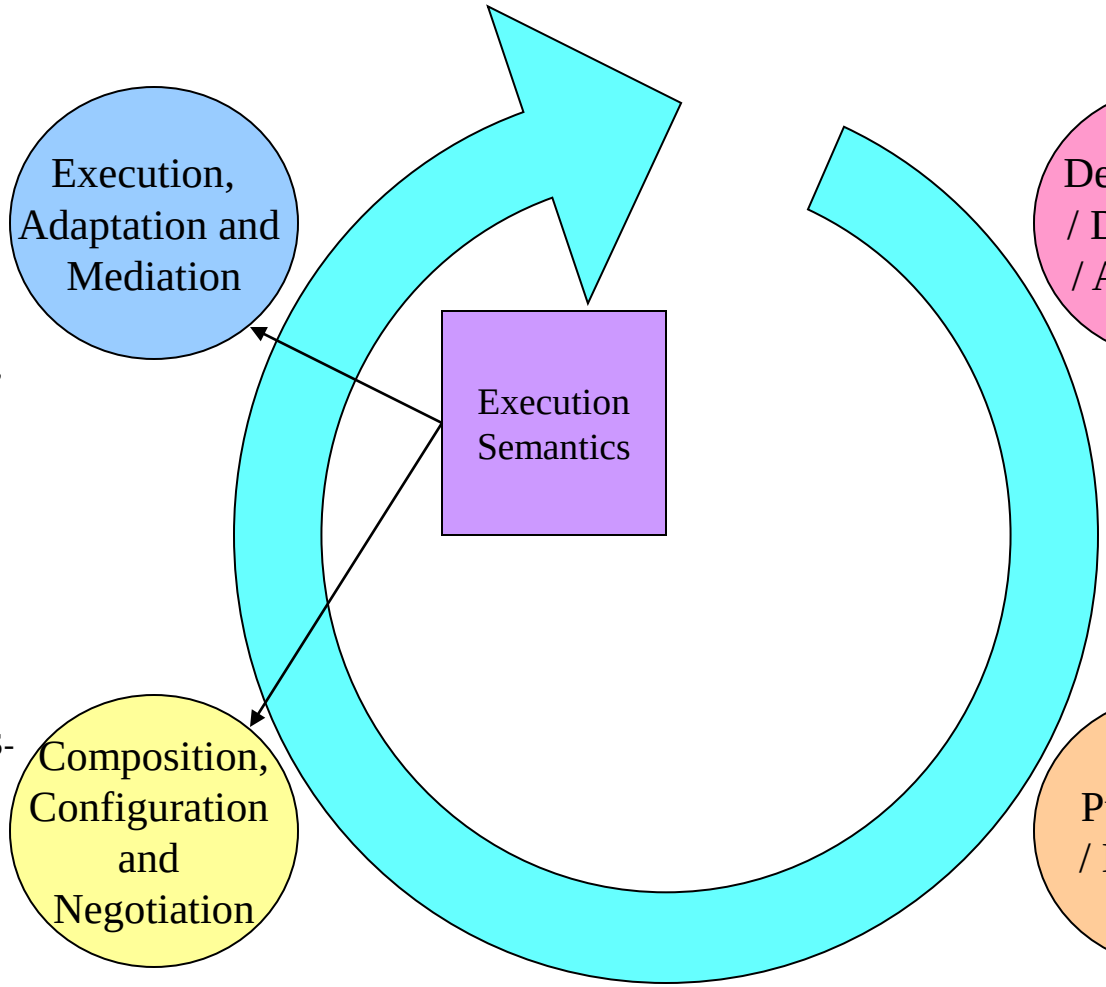

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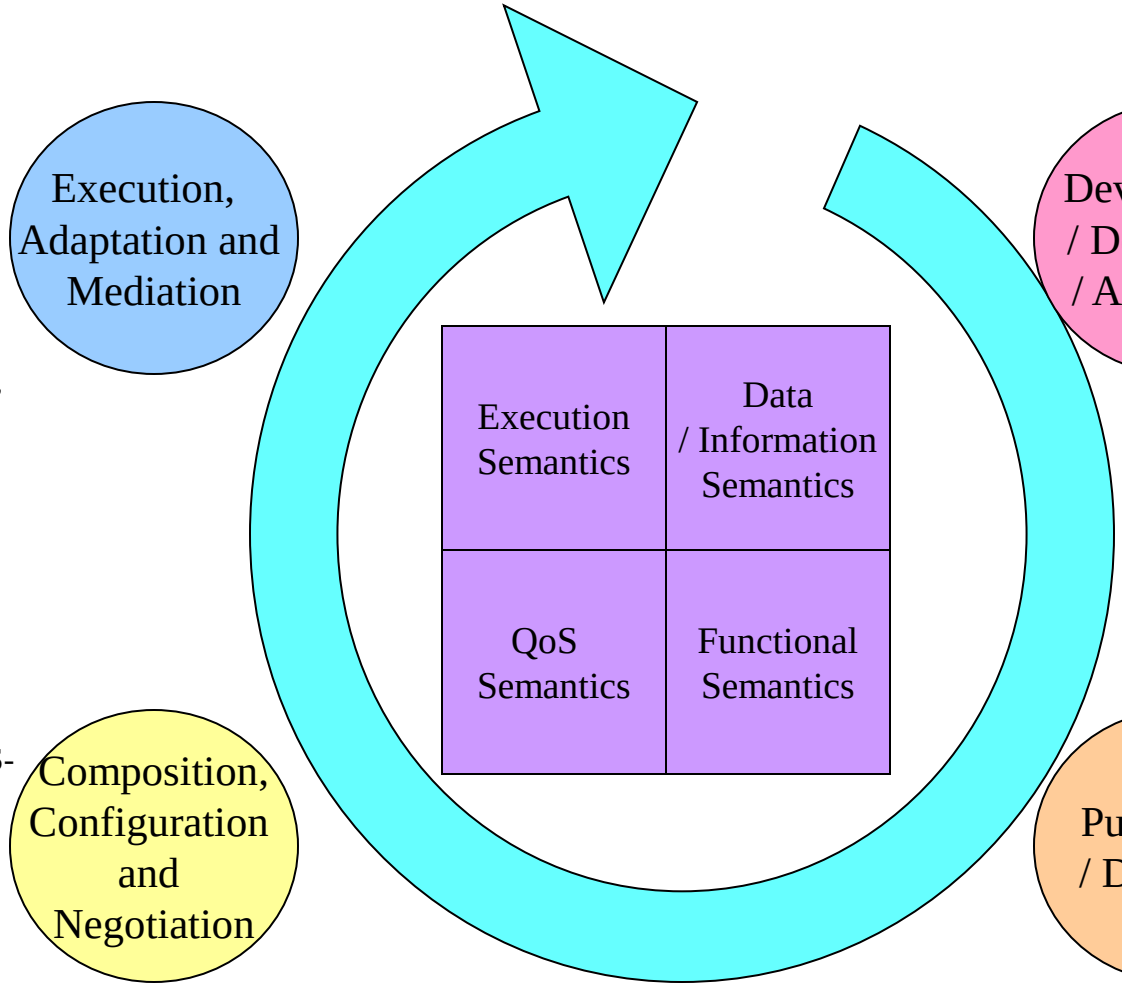

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Semantics for the 4 X 4 Model

- Currently, each tier has its own standard modeling language, e.g. UML or BPMN at Business Process Tier, BPEL for Workflow Enactment Tier, SAWSDL/ WSDL at Partner Services Tier and config files/WSDL at Middleware Services Tier
- Becomes hard to correlate different pieces of the puzzle
- A semantically enriched model that allows us to capture the semantics at each of the four tiers

The 4 X 4 Model

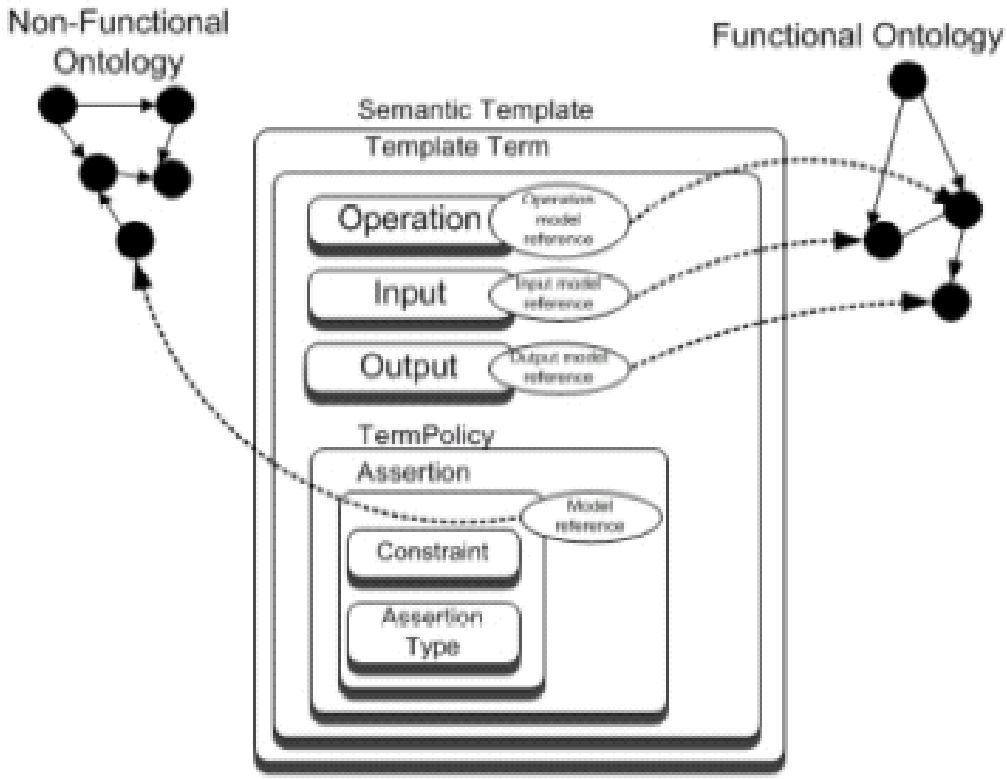
- The 4 X 4 model does not intend to replace any of the current languages. It is a way to add additional description.
- Can be represented by using semantic templates.

That brings us to

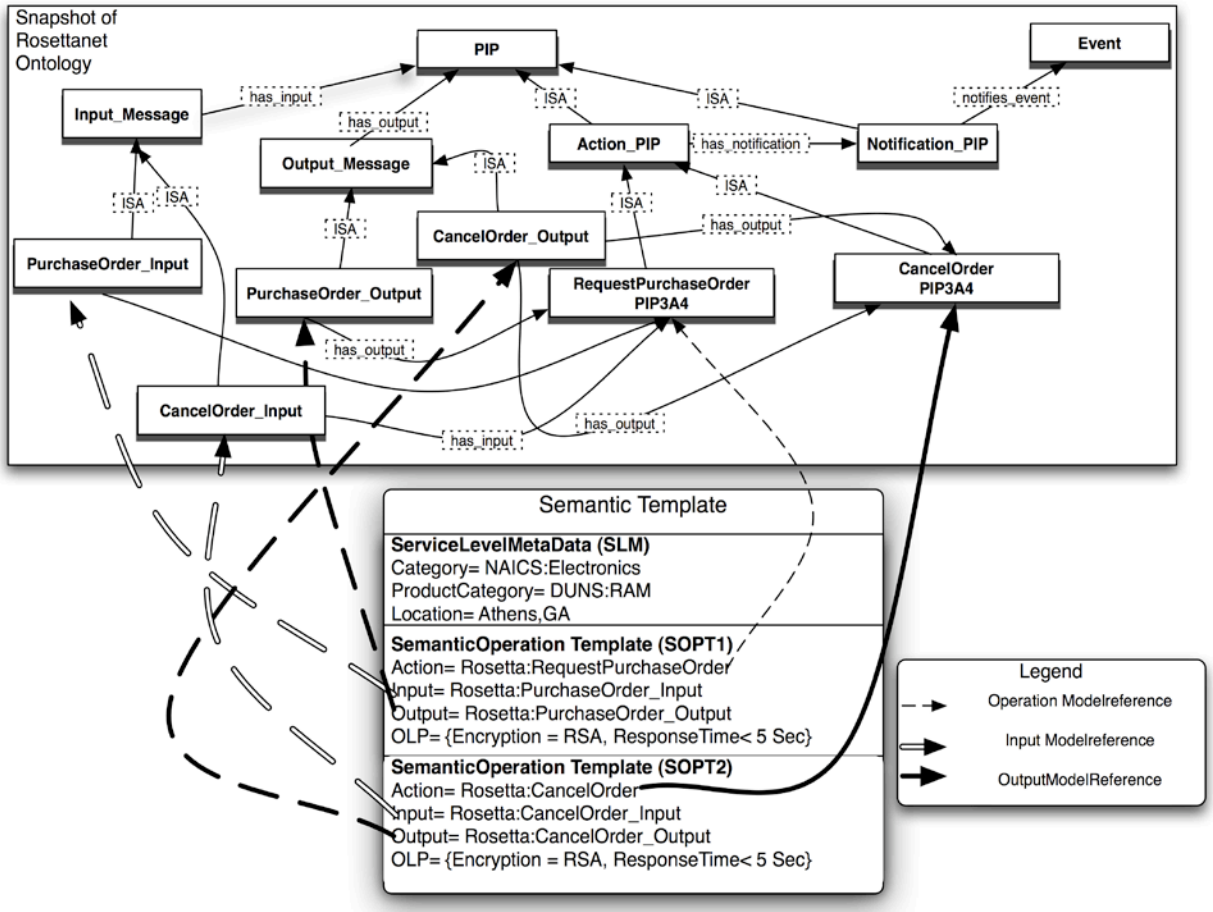
- What are semantic Templates?

Semantic templates

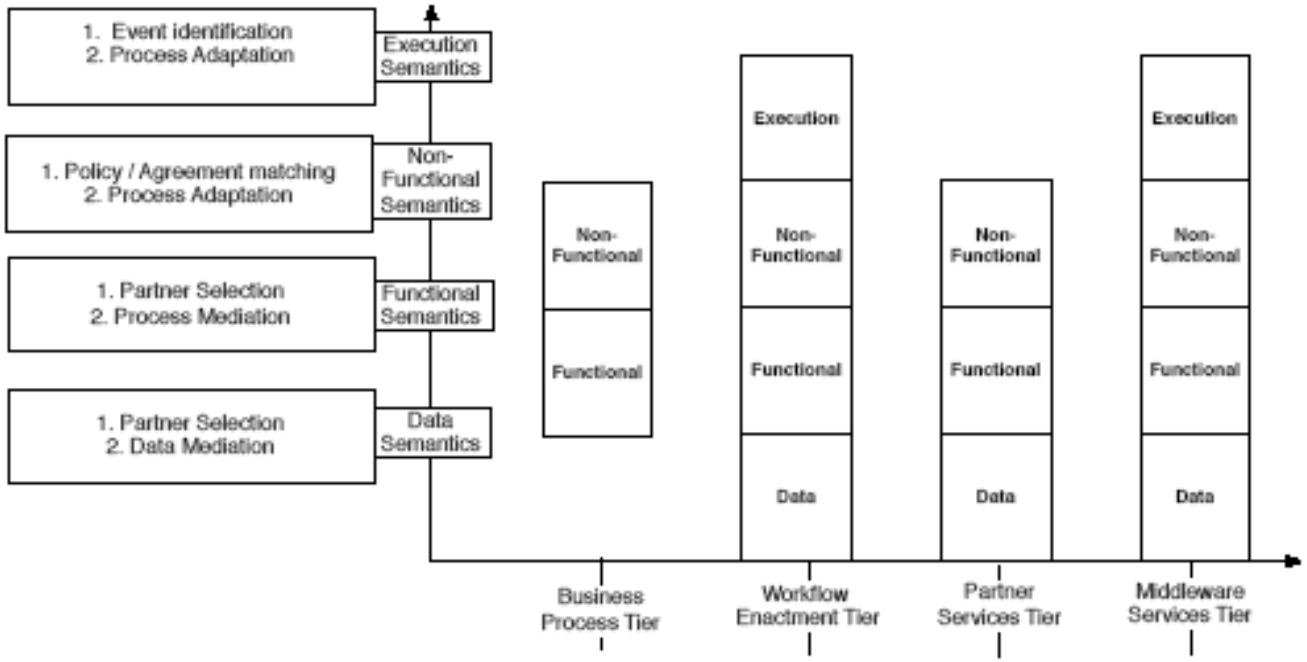
- A way of capturing data / functional /non-functional / execution semantics



Example of a semantic template in the supply chain domain



What semantics at what level?



Why the semantics?

- Business Specification Tier:
  - Need is to capture the functional and non-functional specification. Hence we capture functional and non-functional semantics.
- Workflow enactment Tier:
  - Captures the data flow, control flow and the partner level specifications.
  - Also addresses adaptation.
    - Hence we need all four types of semantics.

Why the semantics?

- Partner Services Tier:
  - Must allow description of partner services including inputs, outputs, what the service offers and the non-functional guarantees and requirements.
    - Data, Functional and Non-Functional semantics
- Middleware Services Tier:
  - Must advertise middleware level capabilities and the policies associated with them.
  - Data mediation can be thought of a middleware level service.
  - Adaptation capabilities must be built into middleware.
    - All four semantics are needed at this level.

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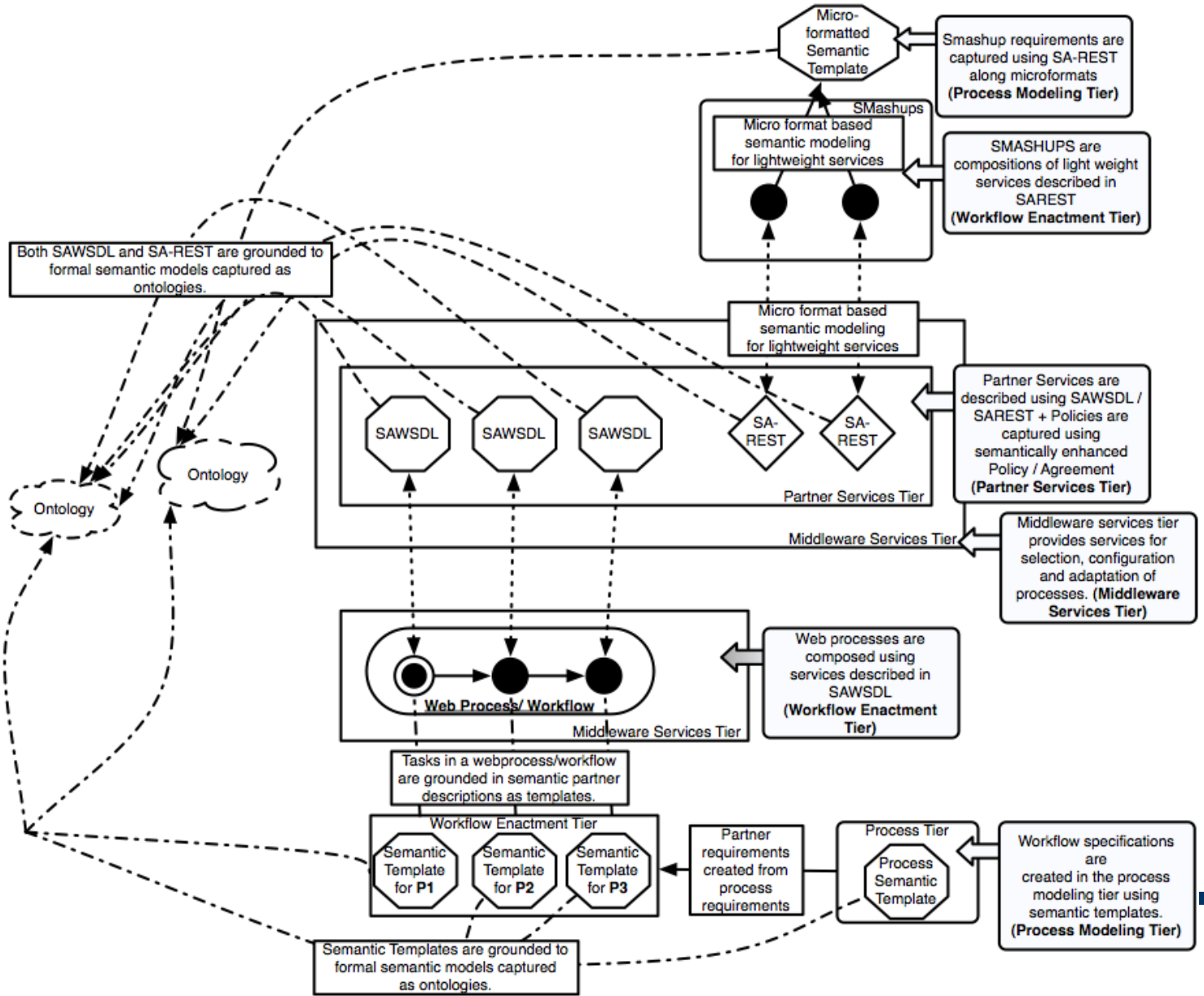
4 X4 Model in Action



4 X 4 Model in Action

- Semantic Templates for capturing process and partner level specifications
- SAWSDL used for SOAP based WS in
  - Semantic publishing and discovery of services
  - Dynamic binding
  - Adaptation
  - Data mediation
- SA-REST (XML + Microformats)
  - Smashups
  - Integration of REST based services
- Enhanced policy descriptions
  - Service selection
  - Process adaptation (Adaptation policies)

4 x4 Model in Action: Summary Example

- A Manufacturer needs to order various components
  - Model business specifications
  - Model Partner specifications
  - Capture adaptation rules and events
    - Needs to include human elements
    - Needs to capture the risk involved in various actions and estimate the probability of various events.
  - Enact and execute business process

How to capture and understand the System, Service and Human aspects ?

- The 4 x 4 Model presents an unified model that integrates the different tiers, that allows to semantically relate the different components across different layers

Illustrating Dynamic Configuration

- Being able to bind partners to a workflow during execution time
- Key tasks include
  - Modeling
    - Creating process and partner level specifications
    - Workflows created with partners described using semantic template
  - Execution
    - Discovery of partners (To be able to discover, we need to address publication as well)
    - Address data heterogeneity
    - Optimization and Adaptation

Conclusions: The 4 x 4 Model in a Nutshell

- The four tiers in Business process modeling are identified as
  - Business Process Tier, Workflow Enactment tier, Partner Services Tier and Middleware Services Tier
- Four types of semantics in SOA lifecycle
  - Data, Functional, Non-Functional and Execution
- 4 x 4 Model integrates the four tiers in business process modeling with the four types of semantics
- Creates a unified construct to relate the different tiers
- Can be captured using Semantic Templates
  - For SOAP services, Semantic Templates are defined using SAWSDL and Policy constructs
  - For REST services, Semantic Tempaltes are defined using XML and Microformats (RDFA)

Conclusion: What does Semantics Bring to the Table?

- Better Reuse
  - Semantic descriptions of services to help find relevant services
  - Allows to study data, functional and non-functional variations between the different tiers
- Better Interoperability
  - Beyond syntax to semantics, mapping of data exchanged between the services (very time consuming without semantics, just as XML in WSDL gives syntactic interoperability, SAWSDL gives semantic interoperability)
  - Functional mediation to address different interaction protocols
- Configuration/Composition
  - Enable dynamic binding of partners
  - Create (S)Mashups dynamically
  - Optimization and adaptation during run time
  - Verify enactments against corresponding business process specifications

Conclusion: What does Semantics Bring to the Table?

- Some degree of automation across process lifecycle
  - Process Configuration (Discovery and Constraint analysis)
  - Process Execution (Addressing run time heterogeneities and exceptions)